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establishing the *Longitudes* over all the Earth. For, besides that these Eclipses are very frequent, the Emerson and Immersion of these *Satellites*, especially in the shadow of *Jupiter*, is so momentany and so sensible, that they may be observed with the greatest exactness, being altogether exempt from those essential inconveniencies that accompany the Eclipses of the Sun and Moon, which also are rare, and whose beginning and end are alwaies doubtful by reason of a certain ambiguous light.

The Longitudes of places at Sea, Capes, Promontories, and divers Islands being once exactly known by this means, would doubtless be of great help and considerable usefulness to Navigation.

Since Monsieur *Borelli* hath found this way of working Glasses, he entrusted the secret of it to a person of the Academy above-mentioned; and he purposeth to publish the same hereafter, with some other considerable Observations touching the same Glasses.

A Letter from Liege concerning Mr. Newton's Experiment of the coloured Spectrum; together with some Exceptions against his Theory of Light and Colours.

Honrd Sir,

M R *Gascoigne* having received your obliging Letter of Jan. 18, with fresh directions from Mr. *Newton*; but wanting convenience to make the Experiment according to the said instructions, he has requested me to supply his want. In compliance with his request I have made many Trials; the issue whereof I here acquaint you with: next, with some exceptions, grounded on Experiments, against Mr. *Newton's* new Theory of Light and Colours.

The vertical angle of my Prism was 60 deg; the distance of the Wall, whereon the coloured *Spectrum* appeared, from the Window, about 18 foot: The diameter of the Hole in the Window-

shuts in length the line *a*, which upon occasions I contrasted to half the said diameter; but still with equal success as to the main of the Experiment. The refracti-
ons on both sides the Prism, were as near as I could make them, equal,

equal, and consequently about 48 deg. 40', the refractive power of Glass being computed according to the *Ratio* of the *Sines* 2 to 3. The distance of the Prism from the hole in the Shutts was about 2 inches: The Room darkned to that degree as to equal the darkest night, while the hole in the Shutts was c-
vered.

Now as to the issue of my Trials; I constantly found the length of the coloured image (transverse to the axis of the Prism) considerably greater than its breadth, as often as the Experiment was made on a clear day; but if a bright Cloud were near the Sun, I found it sometimes exactly as Mr. *Line* wrote you, namely broader than long, especially while the Prism was placed at a great distance from the hole. Which Experiment will not, I conceive, be questioned by Mr. *Newton*, it being so agreeable to the received laws of Refractions. And indeed the Observations of these two Learned persons, as to this particular, are easily reconcileable to each other, and both to truth; Mr *Newton* (as appears by his Letter of Nov. last, wherein more fully he delivers his mind) contending only for the length of the Image (transverse to the axis of the Prism) in a very clear day; whereas Mr. *Line* only maintain'd the excess of breadth, parallel to the same axis, while the Sun is in a bright cloud. Though as to what is further delivered by Mr. *Newton* (*Phil. Transact. N. 80. p. 3077*; and opposed by Mr. *Line*, *N. 129. p. 501.*) namely that the length of the coloured Image was five times the diameter of its breadth; I never yet have found the excess above thrice the diameter, or at most $3\frac{1}{2}$, while the refractions on both sides the Prism were equal. So much as to the matter of fact.

Now as to Mr. *Newton's* Theory of *Light* and *Colours*, I confess, his neat Sett of very ingenious and natural inferences, was to me upon the first perusal a strong conjecture in favour of his new doctrine; I having formerly observ'd the like chain of Inferences upon search into Natural truths. But since several experiments of Refractions remain still untouched by him, I conceived, a further search into them would be very proper in order to a further discovery of the truth of his Assertion. For, accordingly as they are found either agreeing with, or disagreeing from, his new Theory, they must needs much strengthen

then, or wholly overthrow the same. The Experiments I pitch-ed upon for this purpose, are as follow :

1. Having frequently observed , that the form of Objets viewed in the Microscope (or rather of the Microscope it self) consists almost in an indivisible point, I concluded , two very small pieces of Silk , the one scarlet, the other violet colour, placed near together, should, according to Mr. *Newton*'s Theo-ry, appear in the Microscope in a very different degree of clarity, in regard their unequal refrangibility must cause the scarlet rays or species to over-reach the *Retina*, while placed in the due focus of the violet ones, and consequently must oc-casion a sensible confusion in the vision of the former , one and the same point of the Scarlet obje&t affecting several nerves in the *Retina*. Yet upon frequent trials I have not been able to perceive any inequality in this point.

2. The second Experiment I made in Water. I took a brass Ruler, and fastening thereunto several pieces of Silk, red, yellow, green, blew and violet, I placed it at the bottom of a square vessel of Water : then I retired from the Vessel so far as not to be able to see the aforesaid Ruler and coloured Silks otherwise than by help of the refracted Ray. Now, did Mr. *Newton*'s doctrine hold, I conceiv'd, I should not see all the mentioned Colours in a streight line with the Ruler , in regard the unequal refrangibility of different Rays must needs dis-place some more than others. Yet in effect, upon many Trials, I constantly found them in as streight a line as the bare Ruler had appeared in.

3. To advance this Experiment, I adjoyned a second refraction to the former of the Water, by placing my Prism so as to receive *perpendicularly* the refracted species of the Silk and Ruler ; whereby only the emergent species suffered a second refraction. But still with equal success, as to their appearing in a straight line, to the eye placed behind the Prism.

4. To these two Refractions I further added a third, by receiving the coloured species *obliquely* upon the Prism ; where-by both incident and emergent species suffered their respective refractions. But still with the same success as formerly, as to the streight line they appeared in.

For

For further assurance in this Experiment, lest prepossession, occasioned from previous knowledge of the Silks situation in a straight line, might possibly prejudice the judgment of the eye (as sometimes I have observed to happen to the judgment the Eye passeth upon the distance of Objects) I called into the room some unconcerned persons, wholly ignorant what the Experiment aimed at; and demanding whether they saw not the coloured Silks and Ruler in a crooked line? they answered in the negative.

5. The next Experiment I made in uncompounded Colours (as Mr. *Newton* terms them, *Prop. 5 & 13.*) as follows. Having cast two coloured Images upon the Wall, so as the Scarlet colour of the one did fall in a straight line (parallel to the Horizon) with the Violet of the other: I then looked upon both through another Prism, and found them still appear in a straight line parallel to the Horizon, as they had formerly done to the naked eye. Now according to Mr. *Newton's* Assertion of different refrangibility in different Rays, I conceive the Violet rays should suffer a greater refraction in the Prism at the eye, than the Scarlet ones, and consequently both colours should not appear in a straight line parallel to the Horizon.

6. Another Experiment I made in order to some further discovery of that surprizing *Phenomenon* of the coloured Image, which occasioned Mr. *Newton's* ingenious Theory of *Light* and *Colours*, as also his excellent invention of the reflecting *Telescope* and *Microscope*. Having then sometimes suspected, that not only the direct Sun-beams, but also other extraneous light might possibly influence the coloured *Spectrum*, I hoped to discover the truth of this suspicion by means of the Sun-spots, made to appear in the coloured Image by placing a Telescope behind the Prism. But my endeavours proving ineffectual hereinby reason of some intervening difficulties, I thought at length of a more feasible method in order to the designed discovery, as in the following Experiment.

I fastened a very white Paper-circle (about an inch in diameter) upon my Window-shuts; and beholding it through my Prism, I found a Coloured image painted thereby upon my *Retina*, answerable in almost all respects to the former of the

Y y y.

Sun

Sun-beams upon the Wall, especially when the Paper-circle was indifferently well illuminated. This Image indeed appeared contrary to the former as to the situation of Colours, that is, the Scarlet appearing above, the Violet below, though but faint. But this I was not surprized at, having observ'd upon dissecting the eye, that objects are painted on the *Retina* after a contrary posture to what they appear to Sight. Having thus rendred the Coloured image much more tractable than formerly it was, I conceived good hopes of some further discovery in the point mentioned.

In pursuance then of my former suspicion, having fixed my Prism in a steady posture, I caused the paper *C* to be v. Tab.II. applied close up to the Paper-circle *a b d*: whereupon Fig. 5 & 6. the former Violet *d*, and Scarlet colour of *C* vanished into whiteness. Next, I removed the mentioned Circle from the Shuts, and placed it in the open window, supported only by the edge *d*: whereupon, to my astonishment, all the former Colours exchanged postures in the *Retina*, the Scarlet now appearing below, the Violet above; the intermediate Colours scarce discernible. And here, on the by, 'tis very remarkable, that, during this Observation, I clearly perceived both Blew- and Scarlet-light to be transparent, I being able to discern several objects through both, namely Steeples opposit to my window. Whence it follows, that these Colours do in great part arise from the neighbouring light. Lastly, I placed the Paper-circle anew; so as the one half *b* was fastened to the Shuts, the other semicircle *a* being exposed to the open Air. Whereupon the semicircle *a* became bordered with Violet above, Scarlet below; but the other semicircle *b* quite contrary. Hence I make the following Inferences.

First, That not only the Light reflected from the Paper-circle, but also from the ambient Air, hath great influence upon the Coloured image, especially as to the Violet and Scarlet colours. Whence perchance it will not hereafter seem strange, that the coloured *Spectrum* on the Wall is so long, but only that the breadth is not greater. *Secondly*, Were there a more luminous body behind the Sun, we should in all likelihood have the colours of the *Spectrum* in a contrary situation to what they appear in at present: Whence (*thirdly*) it seems to follow, that the

the present scituation and order of Colours, ariseth not from any intrinsecal property of refrangibility (as maintained by Mr. *Newton*) but from contingent and extrinsecal circumstances of neighbouring objects. For accordingly as the body behind the Paper-circle was more or less illuminated than the Circle it self, all the several Colours changed their scituation.

8. The next Experiment was made in order to Mr. *Newton's* doctrine of primary Colours, as *Prop. 5.* Having covered the Hole in the Window-shuts with a thin slice of *Ivory*, the transmitted light appeared yellow ; but upon adding three, four, and more slices, it became red. Whence it stems to follow, that Yellowness of light is not a primary colour, but a compound of Red, &c.

9. The last Experiment was made in reference to Mr. *Newton's* 12 *Prop.* where from his own principles he renders a very plausible Reason of a surprizing *Phænomenon*, related by Mr. *Hooke* ; namely of two liquors, the one Blew, the other Red, both severally transparent, yet both, if placed together, became opake. The reason whereof, saith Mr. *Newton*, is, because if one liquor transmitted only Red, the other only Blew, no rays could pass through both.

In reference then to this point, I filled two small Glasses with flat polished bottoms, the one with *Aqua fortis*, deeply died Blew ; the other with Oyl of *Turpentine*, died Red ; both to that degree, as to represent all obje&ts through them respe&tively Blew or Red. Then placing the one upon the other, I was able to discern several bodies through both : whereas according to Mr. *Newton's* Theory, no obje&t should appear through both Liquors ; because if one transmit only Red, the other only Blew, no rays can pass through both.

These Experimental Exceptions will not, I hope, be unwelcome to Mr. *Newton*, his only aim being the improvement of Natural knowledge, as it is also of,

Sir,
Your humble Servant,
Anthony Lucas.

Postscript.

Just upon the close of the adjoyned Letter, I received from Mr. Gascoine, yours of May the fourth ; wherein you are pleased to favour us with an exact account of the famous Experiment of the coloured Spectrum, lately exhibited before the Royal Society. I was much rejoiced to see the Trials of that Illustrious Company, agree so exactly with ours here, though in somewhat ours disagree from Mr. Newton, as you will understand by the inclosed impartial accounts from,

Sir, &c.

Mr. Newton's Answer to the precedent Letter, sent to the Publisher.

Sir,

The things opposed by Mr. Line being upon Trials found true and granted me ; I begin with the new question about the proportion of the length of the Image to its breadth. This I call a new one ; for, though Mr. Line in his last Letter spake against so great a length as I assign, yet, as it seems to me, it was not to grant any transverse length shorter than that assigned by me, (for in his first Letter he absolutely denied that there would be any such length;) but to lay the greater emphasis upon his discourse whilst in defence of common Optiques he was disputing in general against a transverse Image : And therefore in my Answer I did not prescribe the just quantity of the refracting Angle with which I would have the Experiment repeated : which would have been a necessary

circumstance, had the dispute been about the

* In my first Letter just proportion of the length to the breadth.
Phil. Trans. N. 1221 p509. Yet I added, * this Note, that the bigger the

angle of the Prism is, the greater will be the length in proportion to the breadth ; not imagining but that when he had found in any Prism the length of the Image transverse to the axis he would easily thence conclude, that a Prism with a greater angle would make the Image longer, and consequently that by using an angle great enough he might bring it to equal or exceed the length assigned by me ; as indeed he might : for by taking an Angle of 70 or 75 degrees, or a little greater.

Fig. III.
14 Augusti

Tab. II.
PhTr N°. 128.

Fig. II.
Maculatum
8 Aug

Fig. I.

July 27

28

29

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Aug. 1

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3

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Fig. IV.

15 Ann. 1670

Fig. V.

